US Army Corps
of Engineers
Missouri River Division

MISSOURI RIVER

Big Bend Project
Bad River Aggradation Assessment and Data Compilation

MRD Sediment Memoranda
Number 11
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PURPOSE AND SCOPE

The purpose of this report is to identify any channel trends on the lower six miles of the Bad River, at Fort Pierre, South Dakota. It compiles historic channel geometry, groundwater elevations and sediment transport rate data in one report, and includes a general discussion of sedimentation impacts on river stages and groundwater levels. These parameters will be used if any future aggradation study is necessary in the upper Lake Sharpe area.

The scope of this report is limited to analysis of historic data. Future conditions are not projected herein, and no math modeling techniques were applied.

AUTHORITY

MRD letter dated 24 FEBRUARY 1987, subject: Taking Line Criteria - Missouri River Main Stem Reservoir; requesting a reassessment of existing property acquisition taking lines in the headwaters and tributary arms of Missouri River reservoirs.

1.0. DESCRIPTION OF STUDY AREA

1.1. The Bad River is located in southwestern and central South Dakota, draining an area slightly more than 3,100 square miles. It flows easterly from its headwaters near the Badlands National Monument to Fort Pierre, South Dakota, entering the right bank of the Missouri River at 1960 river mile 1065.2 about six miles below Oahe Dam. The study area is limited essentially to the lower six miles of the Bad River. Plate 1 is a map showing the Bad River and surrounding area.

1.2. Topography. The basin is elongated, approximately 100 miles long and 40 miles wide consisting of low hills, buttes and rolling grasslands.

1.3. Climate. Climate is semiarid with the average annual precipitation ranging from 14 inches per year near the headwater to 18 inches per year near the mouth. Temperatures can range from -40 degrees F to 120 degrees F. The last spring frost generally occurs during the second week of May and the first fall frost during the last week of September.

2.0 HISTORIC DATA

2.1. Data analyzed in this study consists of historic cross section data, area and capacity data, streamflow records, sediment discharge records, and groundwater data.

2.2. Cross Section Data. Six sediment ranges are located on the Bad River 0.1, 0.9, 1.6, 2.7, 4.0, and 5.7 river miles above its confluence with the Missouri River (see Plate 2). These ranges have been surveyed six times, with the original survey for individual cross-sections occurring during different years between 1952 and 1960 (in this report, for standardization of plots, all original survey years will be shown as 1958 except on cross-section plots). All cross-sections were surveyed in 1965, 1971, 1975, 1983 and 1989. Missouri River sediment ranges located near the mouth of the Bad River and analyzed in this study have been surveyed at least six times, generally during the same time period as the Bad River ranges. All cross section data was obtained from Corps records.

2.3. Area and Capacity Data. Area and capacity curves and tables were developed by the Corps after each survey. These curves show the net change in capacity (i.e., volume lost to sediment deposition) below specific pool elevations from one survey year to the next. Programs used for area capacity analysis also provide data on the relationship between capacity and elevation for reservoir segments. The upstream and downstream boundaries for each segment are the sediment range lines. For the Bad River, segment 4040 is bounded by range 0.1 and 0.9, segment 4041 by ranges 0.9 and 1.6, segment 4042 by ranges 1.6 and 2.7, segment 4043 by ranges 2.7 and 4.0 and segment 4044 by ranges 4.0 and 5.7.

2.4. Streamflow Data. Streamflow data for the Bad River near Fort

Pierre, South Dakota (station 06441500) was obtained from published U.S. Geological Survey records. The period of record is from 1928 to present. This gage is located about 6 miles upstream of the confluence as shown on Plate 2.

2.5. Sediment Discharge Data. Sediment discharge data was gathered and published by the Corps from 1947 to 1971, followed by the U.S. Geological Survey from 1971 to present.

2.6. Groundwater data. Sixteen piezometers were established at Fort Pierre, South Dakota between 1959 and 1973 at the locations shown on Plate 3. Wells numbered 1 through 10 were installed in 1959, 11 and 12 in 1968, and 13 through 17 in 1973. The original piezometers were laid out in two lines with proposed well number 4 located at the intersection of the lines, however well 4 was never established due to a layer of shale at this site. Well number 12 was destroyed in 1970.

2.6.1. The period of record starts soon after the wells were installed and continue to 30 April, 1985. Observations vary from year to year (e.g. one reading in 1964, 24 readings in 1968, 8 readings in 1976). All observations were obtained, recorded and stored by the Corps.

3.0. OBSERVED TRENDS

3.1. Channel Geometry. Plates 4 through 9 are cross section plots of the Bad River sediment ranges. Plates 12 through 15 are profile plots of thalweg, average bed, channel width and cross section area. Plates 16 through 19 show temporal changes in the above data at each cross section. The thalweg is the deepest point in a cross section or a line connecting the deepest points of a channel. The other hydraulic parameters are based on a reference plane which in this study is an imaginary line approximately parallel to the thalweg and at an elevation that is above where most bank changes occur, but below the top of the bank. The cross section area is the computed cross section area below the reference elevation. The channel width is the width of the channel at the reference elevation and the average bed elevation is equal to the reference elevation minus the cross section area divided by width. Observations from these plots are discussed below.

3.1.1. Each cross section shows variation in the channel geometry parameters from one survey year to the next, but the overall change during 30 plus years of record is minimal. Also, parameters for different cross sections during the same survey year do not show comparable increases or decreases (i.e., Plate 17 shows that the average bed increases between survey years at some cross sections and decreases at others).

3.1.2. Plates 10 and 11 show the Missouri River sediment ranges just below and above the mouth of the Bad River. Range 1116.2 reveals some deposition in the middle of the river and a couple of hundred feet of bank erosion on the right bank. Most of these changes occurred in the years shortly after the LeFrambosie Island closure. Range 1116.6 shows very little change in the Missouri River channel except for some deposition on the left

side near LeFramboise Island.

3.2. Channel Volume. Plate 20 is a plot of the change in Bad River volume by segment over time. Table 1 denotes numerical changes in total volume and sediment depletion rates between survey years. The graph indicates a decrease in capacity through the 1960's and early 1970's followed by increasing volume through the eighties. Net capacity loss during the period of record is minor. Plates 21 through 25 reveal volume changes between the original survey and subsequent survey years, while Plates 26 through 29 show the volume changes between successive survey years.

3.3. Stage Trends. Plate 30 shows stage trends (Bad River station near Fort Pierre) over time for different water discharges. This data was taken from historic rating curves provided by the South Dakota U.S. Geological Survey. Again, some variation in stage is evident for a given discharge with time, but overall the change is minimal. Looking at only the first and last points on the chart reveals an increase in stage for the higher flows. However, the lower flows which have more field observation points show practically no change.

3.4. Sediment and Water Discharge. Plate 31 shows cumulative sediment and water discharge at the Bad River gaging station since 1948. The generally uniform slope of both curves for the period 1953 to the early 1980's indicates that water and sediment quantities, as well as the relationship between the two, have remained relatively steady with time. Of specific note, however, is the divergence of the two curves since the early 1980's. This observed increase in water discharge, coupled with the continued uniform sediment discharge, would tend to indicate a decrease in sediment concentration for the basin. While the period of this observation is too short to indicate a long term trend, it merits continued monitoring. The sharp increase at the beginning of both graphs reflects the 1952 flood event.

3.5. Groundwater. Groundwater levels rose approximately six feet from 1959 to 1973, then remained generally at the same levels until data collection ceased in 1985 (see Plates 32 through 46). This increase in the water table was examined and explained in a 1973 Corps of Engineers study entitled "Groundwater Investigation at Fort Pierre, South Dakota". A brief overview of the findings is found in the following paragraph.

3.5.1. The behavior of the groundwater at Fort Pierre is influenced to some degree by stages on the Missouri River (i.e. an increase in the river stage will cause an increase in the groundwater level). Two probable factors account for the rise in measured groundwater levels between 1958 and 1973. First, nearly all excess available water that would have passed by Fort Pierre between 1959 and 1963 was stored upstream of Oahe Dam to fill the three upstream reservoirs. Consequently the Missouri River stages and groundwater levels at Fort Pierre were abnormally low during these years. The later operation of Oahe and Big Bend Projects altered the flow regimen of the Missouri River at Fort Pierre, resulting in higher stage level conditions and likely contributing to the higher groundwater levels experienced by

TABLE 1

LAKE SHARPE
SEDIMENT DEPLETION VOLUMES AND RATES
ON BAD RIVER, R.M. 0 TO R.M. 6

Volume Change Due To Sediment Accumulations at Maximum Pool Elevation

BAD RIVER (Capacities to Elevation 1430.0 M.S.L.)

DATE OF SURVEY	CAPACITY BELOW MAXIMUM POOL ELEVATION Ac-Ft	VOLUME LOST TO SEDIMENT DEPOSITION BETWEEN SURVEYS Ac-Ft	VOLUME LOST TO SEDIMENT DEPOSITION SINCE CLOSURE Ac-Ft	SEDIMENT DEPLETION RATES BETWEEN SURVEYS Ac-Ft/Yr	SEDIMENT DEPLETION RATES SINCE CLOSURE Ac-Ft/Yr	PERCENT DEPLETION BETWEEN SURVEYS TOTAL	PERCENT DEPLETION BETWEEN SURVEYS AVERAGE ANNUAL
1958	1117.8						
		17.5		2.5		1.6	0.2
1965	1100.3		17.5		2.5		
		77.8		13.0		7.1	1.2
1971	1022.5		95.3		7.3		
		49.9		12.5		4.9	1.2
1975	972.6		145.2		8.5		
		6.1		0.8		0.6	0.1
1983	966.5		151.3		6.1		
		-88.3		-14.7		-9.1	1.5
1989	1054.8		63.0		2.0		

1973. Comparing the average annual discharge in 1972 with eight years of similar annual discharges before 1958 shows that the average Missouri River stage was 2.2 to 3.7 feet higher in 1972.

4.0 CONCLUSIONS

4.1. Analysis of the available data reveals that little net change has occurred in the observed parameters over the period of record. A summary from the analysis on the Bad River's lower six miles is summarized as follows:

a. Cross-section geometry, area, and capacity data changes can usually be observed between successive surveys, but alterations are minor and no overall trends are discernible.

b. A cumulative water and sediment discharge plot shows a generally uniform slope, however the sediment curve seems to have become slightly flatter since the mid 1960's. Also, a divergence of the curves in the 1980's might be a sign of decrease sediment concentration in the basin. Continued monitoring of sediment discharge should continue.

c. Given the absence of noticeable changes in river stage levels due to sedimentation impacts, it appears unlikely that sedimentation in the Bad River contributed to the rise in groundwater levels at Ft Pierre. The groundwater levels increased approximately six feet between 1959 and 1973, then remained at relatively the same levels until data collection ceased in 1985. This increase was examined and explained in a 1973 Corps of Engineers study entitled "Groundwater Investigation at Fort Pierre, South Dakota". The study found that the groundwater at Fort Pierre is related to some extent to the Missouri River stages. Two main factors altered the river stage which in turn effected groundwater levels. First, practically all excess water in the Missouri River above the Oahe Dam was stored in the upstream reservoirs between 1959 and 1963 causing a 2 to 4 foot drop in the Missouri River stages at Pierre, South Dakota during the early groundwater collection period. Second, backwater effects from the operation of the Big Bend Project and higher releases from the Oahe Project caused an increase in river stage at Fort Pierre, South Dakota. The 1972 river stage at Pierre, South Dakota was 2.2 to 3.7 feet higher than for eight similar pre-project average annual discharges.